Adapting the use of AEM for greenfields VMS exploration under cover

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SUMMARY

Exploring under conductive cover in the Bryah and Yerrida Basins of central Western Australia poses serious limitations to the use of AEM for direct targeting of conductive bedrock anomalies possibly associated with VMS deposits. We present an alternative approach, where robust geological modelling based on AEM plays a major role in exploration strategy.

The AEM is not only directed at targeting of bedrock conductors, but importantly, at supporting the development of a robust basin-wide geological model to identify priority areas for follow up surface geophysics and geochemistry. A patchwork of AEM surveys has been acquired by various explorers and contractors between 2009 and 2018 (Figure 1). Systems and system specifications vary greatly. Accurate geological interpretation cannot be derived from either raw data or fast/approximate conductivity products provided by contractors. All datasets require reconciliation with a common workflow and robust modelling strategy, which also takes prior geological information into account. Historic AEM data have been reprocessed and reinverted. The central block has just been flown and is currently subject to the same workflow.

The end result will be a seamless basin-wide 3D conductivity model (extending over 6500 km^2) which will inform the geological interpretation and subsequent follow-up exploration efforts. The new 3D models already allow clear identification and modelling of pyritic shale horizons, enabling the anomalous geochemistry and strongly conductive nature of these units to be discounted in the targeting process.

INTRODUCTION

Mineral exploration in the Yerrida and Bryah Basins (regional geology in Figure 2) is hampered by extremely poor exposure, deep weathering and palaeochannel cover. Geochemical analyses of surface samples produced strong metal and pathfinder anomalies demonstrated to be associated with continuous (stratigraphic) disseminated pyrite in carbonaceous shales, with no economically significant mineralisation. Given the poor exposure and low contrast in the aeromagnetic response (Figure 1), historical geological interpretations of the Yerrida Basin in particular failed to define areas within which pyritic carbonaceous shales occur. This has led to repeated unsuccessful historic exploration campaigns.

One of the key requirements of the AEM is therefore to map the pyritic shale horizons. Another is identifying palaeochannels infilled with fine grain material, in order to select the appropriate exploration methods to be adopted in these areas. In order to justify the approach we champion in this paper, we first present the AEM data as maps of voltage values. This is the point where exploration companies often stop, looking merely for the red blob at late times. Figures 3 and 4 show the normalised voltage (pV/Am4) at selected times after turn off, recorded by the AEM systems across the tenure. We chose, from all systems, "early-time" gates closest to ~150 μs and the "mid-late time" gates at ~3 ms. Obvious system dependent features in the data (the normalisation by the effective moment does not take the waveform shape out of the system transfer function) hinder seamless merging. Obvious IP effects are also present. Inspection of these maps within similar systems (e.g, all VTEM) yields a perception of the wealth of information contained in the data, but does not allow understanding the 3D variability of the conductivity, nor the possible geological sources associated to the anomalies. The need to reduce the exploration space warranted the effort to extract as much information from the AEM data as possible.

METHODS

The AEM was tackled one dataset at the time, keeping in mind a merged product would be delivered for geological mapping. The first step for accurate modelling of AEM data entails a proper description of the transfer function of each system in order to avoid serious artefacts in the inversions. Each of the actual digital waveforms made available was closely and evenly sampled, down to the end of ramp down. Notice that they often differ significantly from the nominal waveforms. The EM and navigation data was then custom processed, starting from the raw (i.e., with the lowest amount of pre-processing by the contractors). Noisy gates are culled and/or have their uncertainty increased. Full non-linear inversion (based on exact 1D forward solution of layered earth) with spatially constrained inversion (SCI) was next. Many preliminary inversions with different regularisation settings were carried out on each dataset and assessed against the limited ancillary geological information available. We therefore converged to one common setting that was applied to all blocks for the final inversions, carried out separately for each dataset. Depth of Investigation was calculated and the results cropped with it to avoid over-interpreting parts of the models associated to little sensitivity. The possible relevance of AIP modelling over some of the AEM subsets is the subject of ongoing research.

RESULTS

The results were then merged together into a common database, from which maps, cross sections and 3D conductivity voxels were derived. Figure 3 reports conductivity slices at different depths. They show coherent, seamless features across the different datasets. They can then be put into geological contest. For example, the new 3D models allow clear identification and modelling of the pyritic shale horizons (Johnson Cairn and Red Bore Black Shales). Figure 4 shows a 3D view of the SE corner, with associated interpretation. The advanced modelling and derived interpretation enable the anomalous geochemistry and strongly conductive nature of the pyritic shales units to be discounted in the targeting process. Discrete conductors with more subtle geochemical responses in prospective stratigraphy can be identified and evaluated. In addition to the identification of the pyritic carbonaceous shales the new 3D models allow palaeochannels to be modelled in 3D. Whilst the conductivity of the basement below the highly conductive palaeochannels is rarely well resolved, the modelling process allows appropriate exploration methods (drilling for geochemical samples and DHEM) to be adopted in palaeochannel covered areas. Neither the pyritic shale horizons nor the palaeochannels could have been mapped with the degree of confidence needed to drive the exploration forward if simply merging data/deliverables provided by contractors.

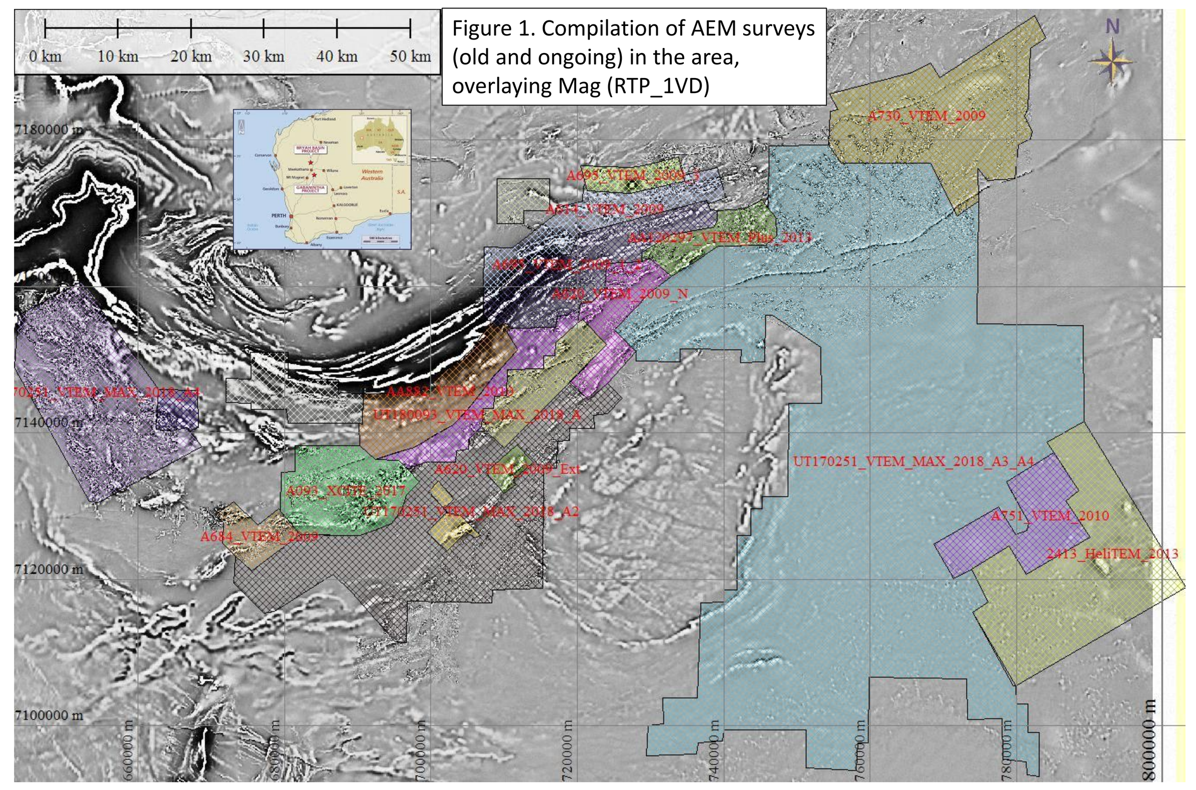

Figure 1. Compilation of AEM surveys (old and ongoing) in the area, overlaying Mag (RTP_1VD)

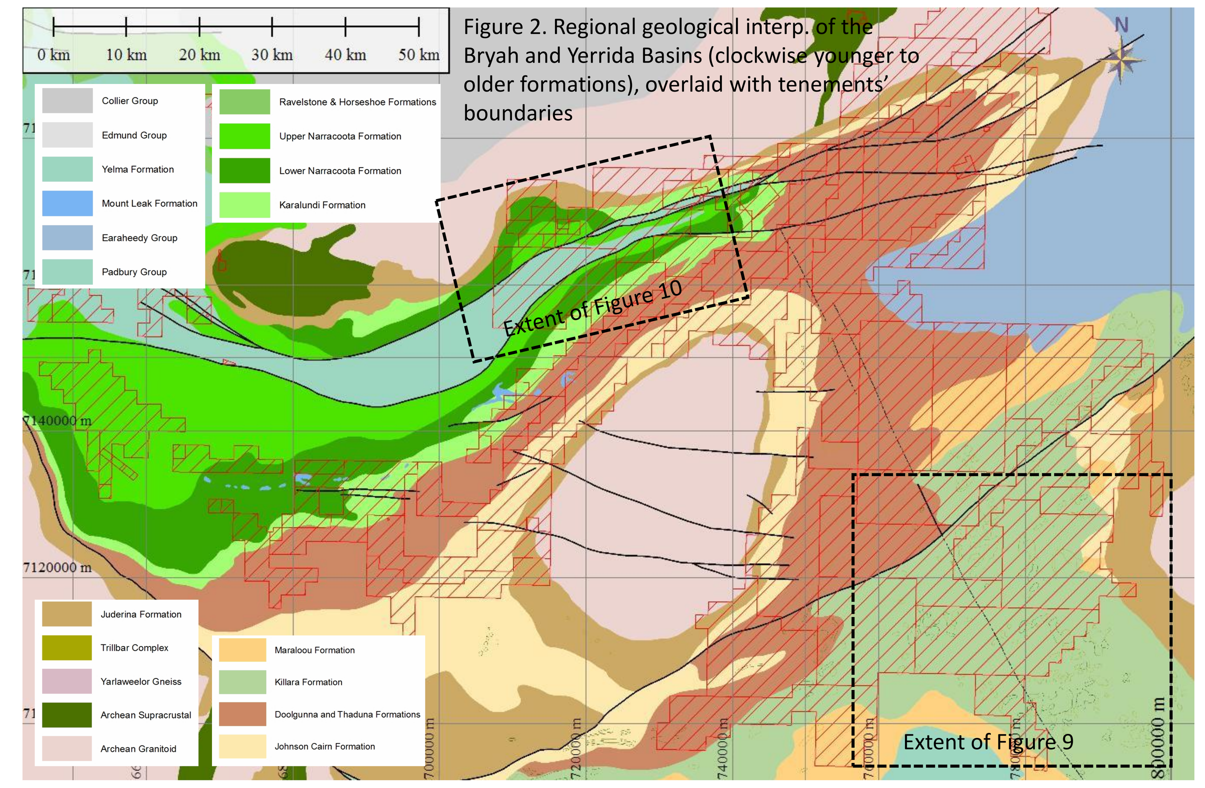

Figure 2. Regional geological interp. of the Bryah and Yerrida Basins (clockwise younger to older formations), overlaid with tenements' boundaries

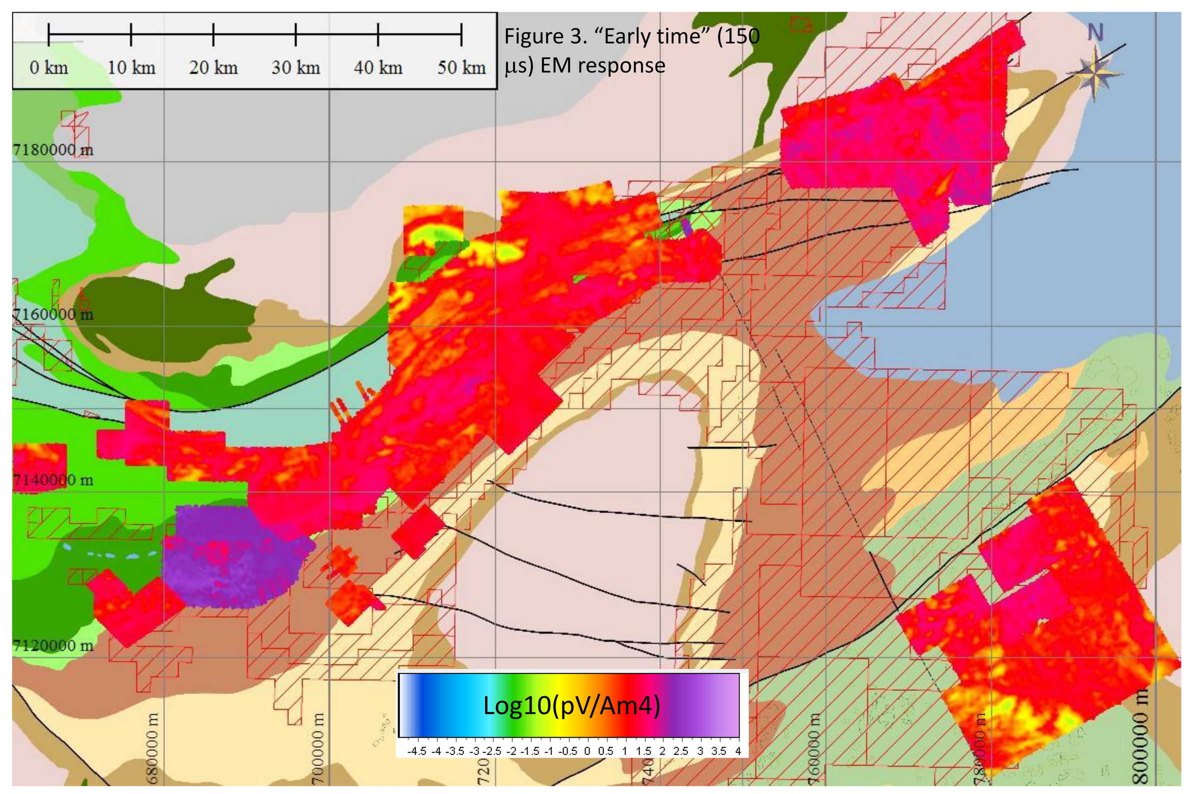

Figure 3. "Early time" (150 μs) EM response

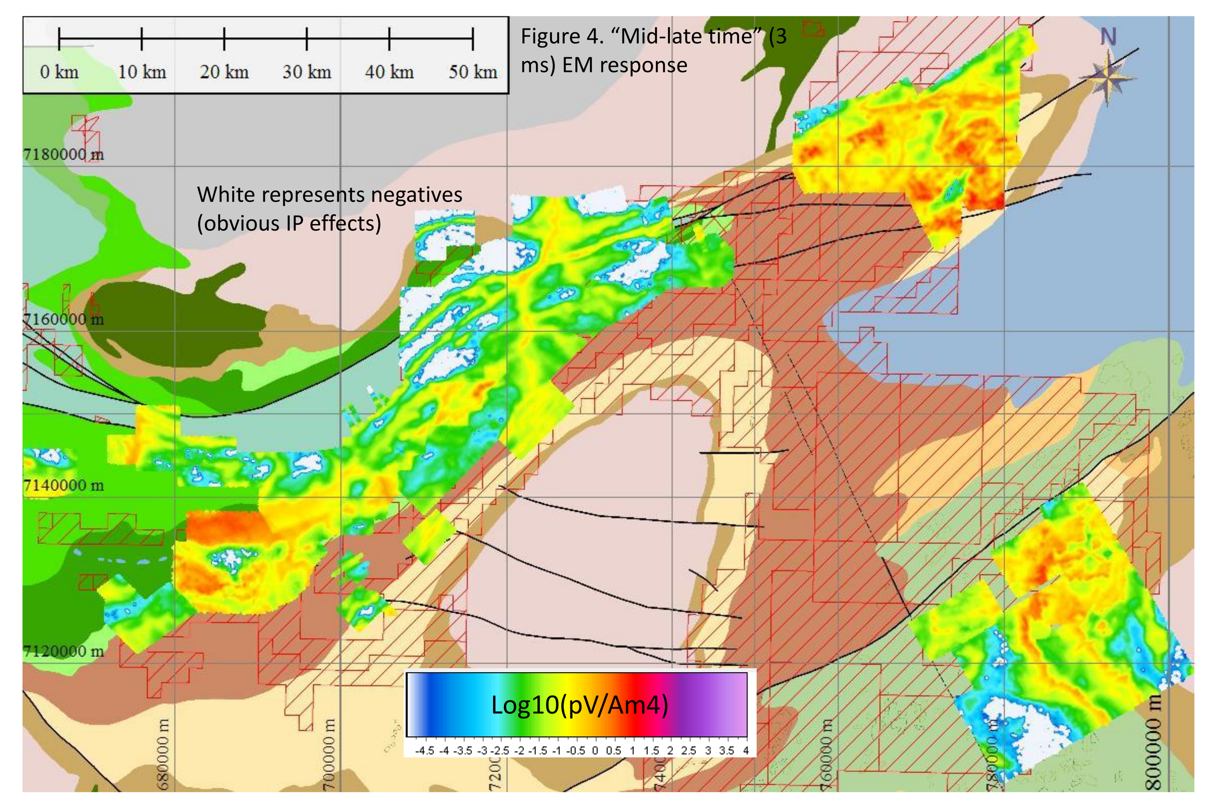

Figure 4. "Mid-late time" (3 ms) EM response

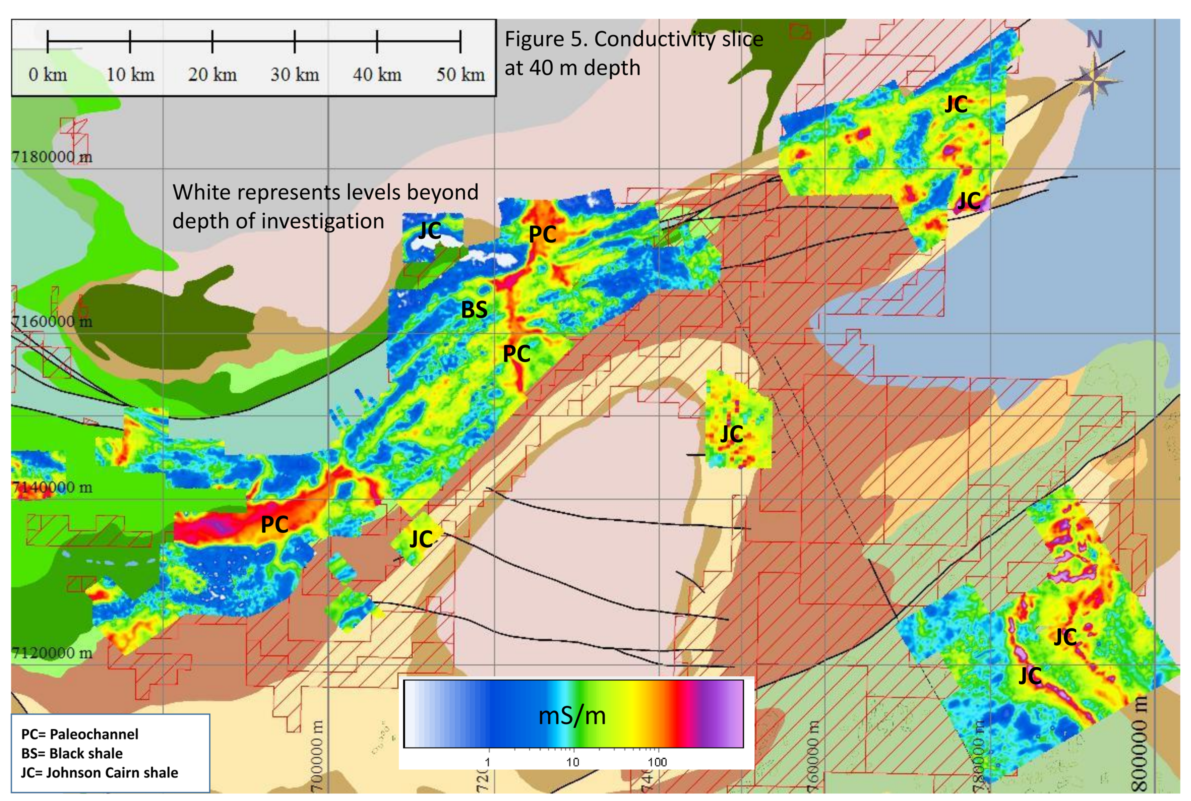

Figure 5. Conductivity slice at 40 m depth

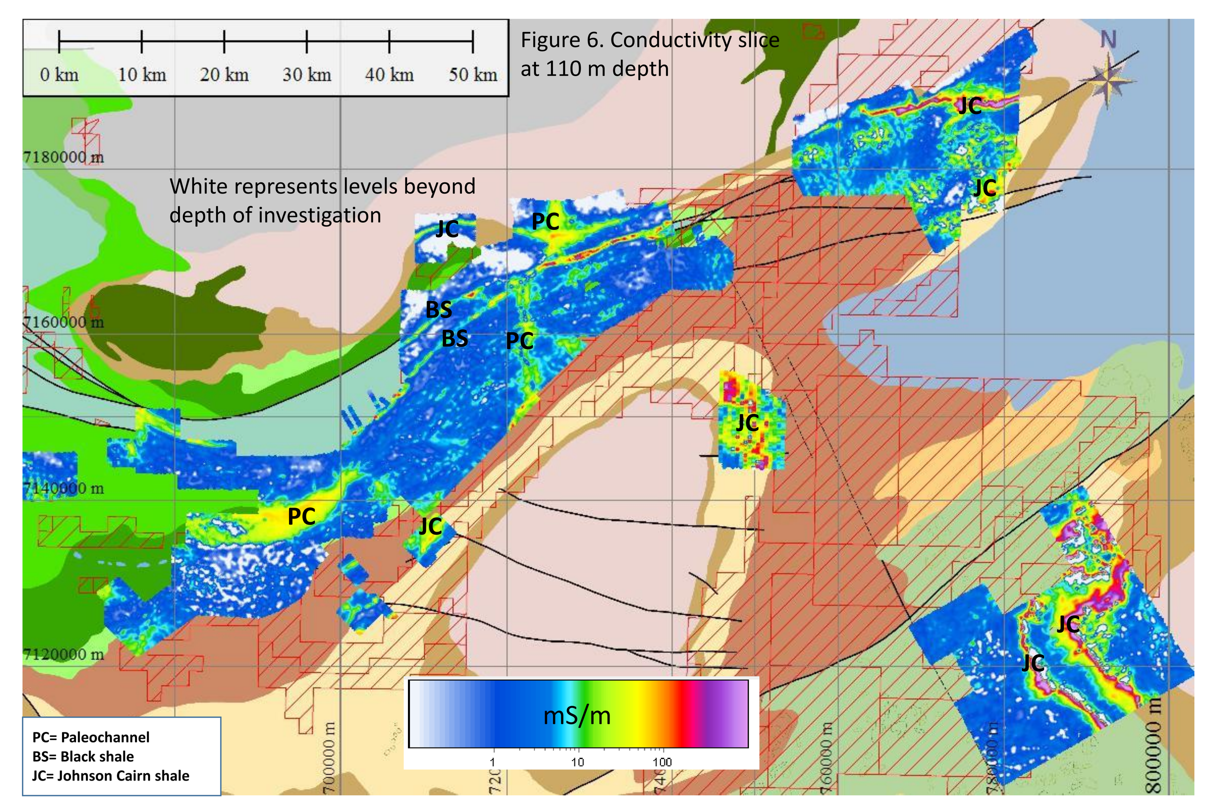

Figure 6. Conductivity slice at 110 m depth

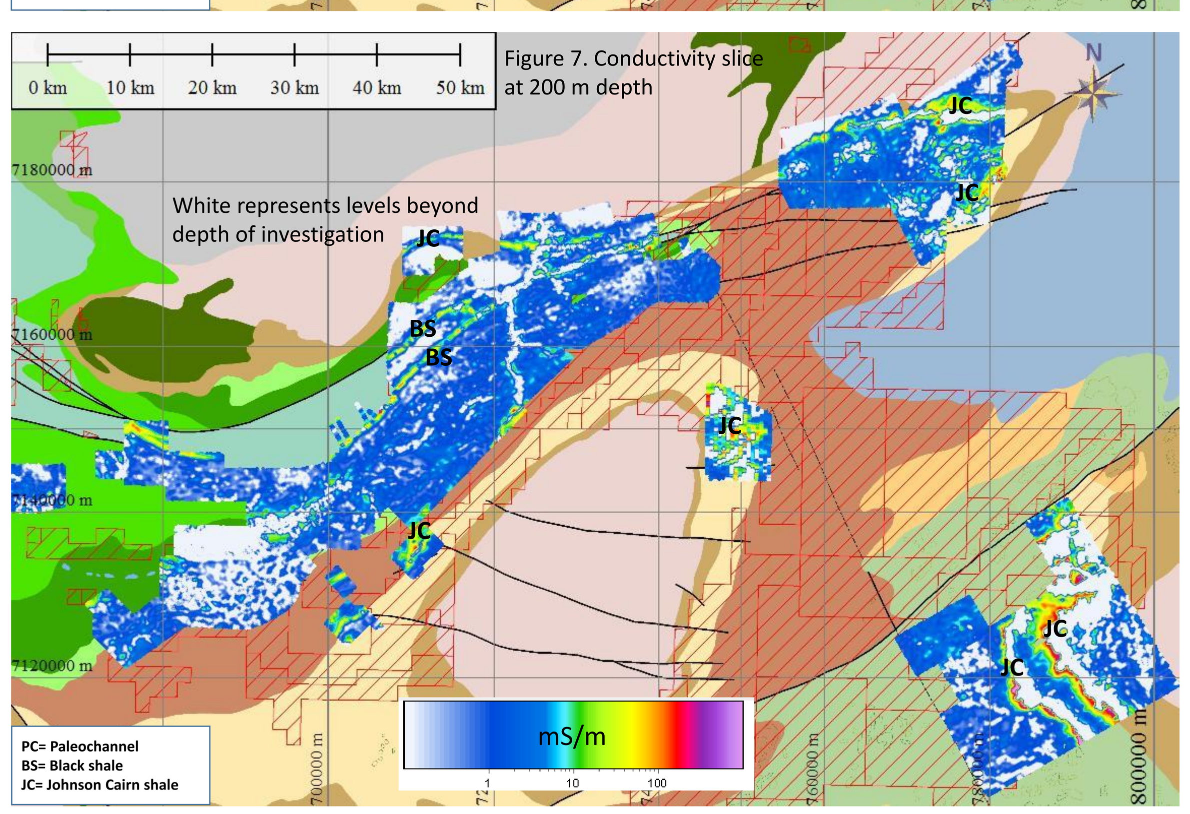

Figure 7. Conductivity slice at 200 m depth

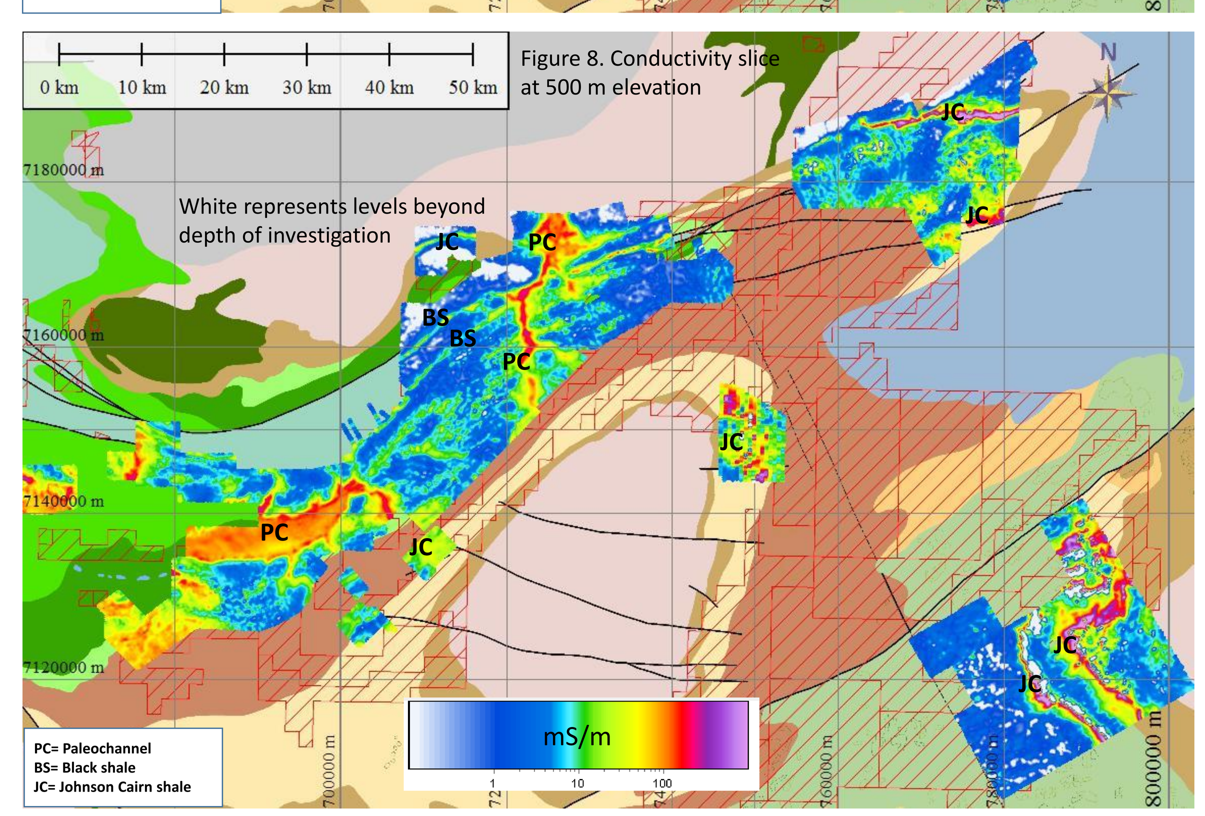

Figure 8. Conductivity slice at 500 m elevation

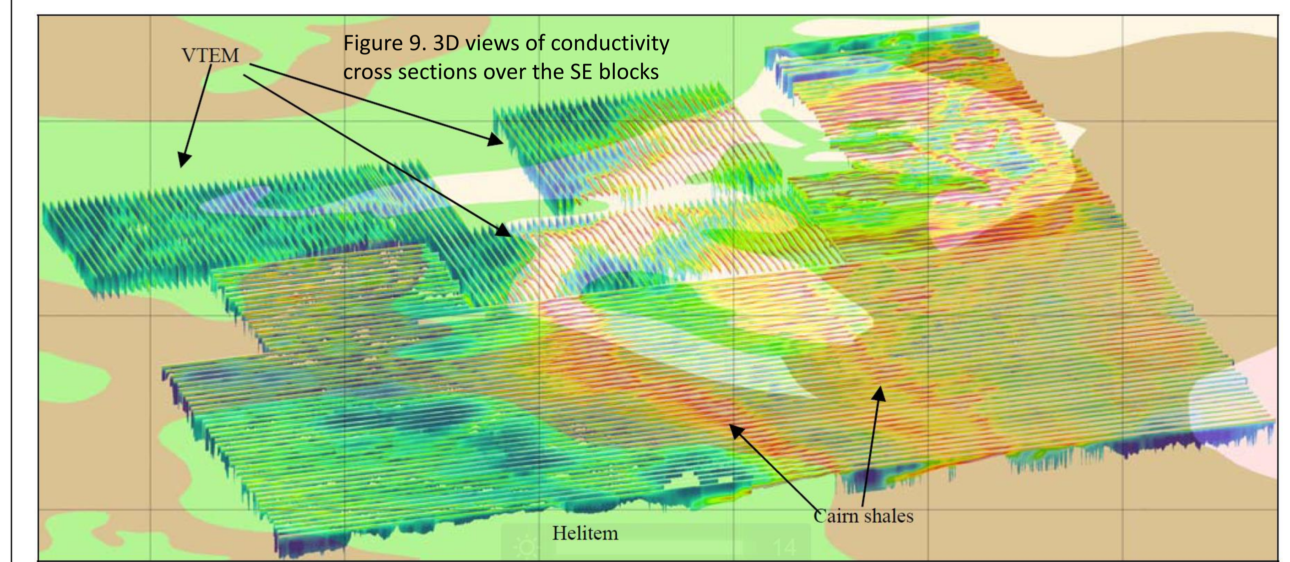

Figure 9. 3D views of conductivity cross sections over the SE blocks

A LITTLE EXTRA: MAPPING BEDROCK TOPOGRAPHY

This approach to AEM data can also provide valuable contribution to enhanced planning of future exploration activities: mapping of bedrock topography. The existing knowledge of bedrock topography relies on highly variable spatial samples / drillholes. The quality of the drilling and associated interpretation also varies. A improved knowledge of bedrock topography would allow much more efficient and effective use of ground geophysics, e.g., EM, IP or gravity. It also represents relevant information to be added to other modelling, such as inversion of potential field data.

In order to derive bedrock topography from the AEM data, the SCI inversion results were first compared against the local available bedrock information. The general understanding is that the Proterozoic bedrock would be more resistive than cover. However, over such a vast area, there are places (e.g., the pyritic shales) were bedrock is expected to be conductive. A statistical analysis of the bedrock conductivities showed a poor correlation between specific conductivity values and bedrock depth. This can be due to a number of factors; of both geophysical (e.g., low sensitivity, IP effects) and geological origin. Regardless of the cause, the poor correlation between resistivity values and bedrock implies that using a given resistivity value for prediction of (fresh) bedrock depth would often result in very large errors. We therefore moved to conductivity vertical gradients as possible predictors. The correlation with known bedrock topography improved significantly. Figure 10 shows the predicted bedrock elevation. The central (blue) Gascoyne river palaeochannel is clearly visible.

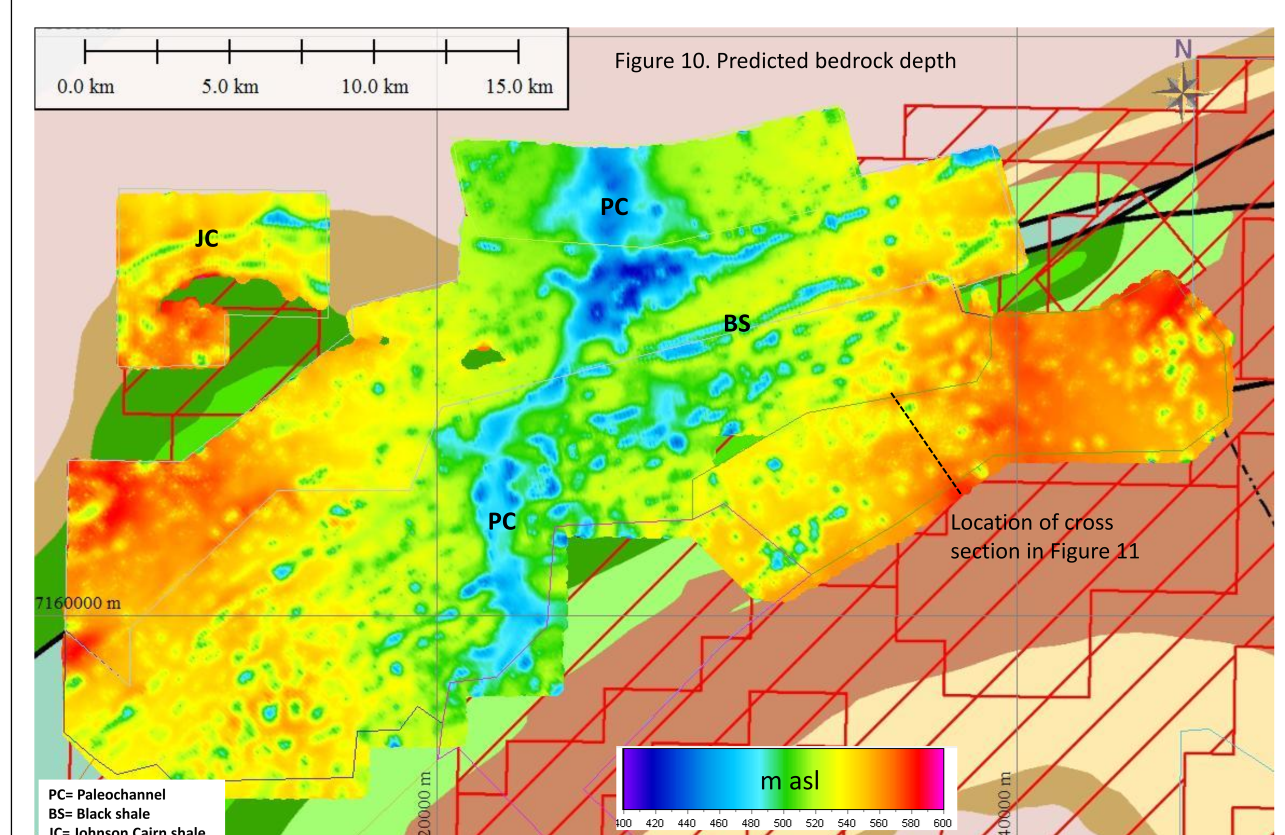

Figure 10. Predicted bedrock depth

As mentioned above, IP effects are present in the area. If not modelled, they could have a negative effect (also) on bedrock prediction. Figure 11 below compares bedrock information from drilling against the conductivity cross-section for one VTEM line (cfr Figure 10 for its location). The top results were obtained modelling IP effects in the AEM data (AIP), the bottom ignoring them. *We invite you to attend W4b3 on Wednesday for more details on AIP)*.